# Nickel and iron as attenuator materials for helix TWT

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3 authors:

Vikas Kumar
Sharda University


Anil Vohra
Kurukshetra University


Vishnu Srivastava
Central Electronics Engineering Research Institute

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# Nickel and iron as attenuator materials for helix TWT

Vikas Kumar[1], Anil Vohra[2] & Vishnu Srivastava[3]
[1]Asia-Pacific Institute of Management, Jasola, Sarita Vihar, New Delhi 110 025, India
[2]Electronic Sc. Department, Kurukshetra University, Kurukshetra, Haryana 136 119, India
[3]Microwave Tubes Area, CEERI, Pilani, Rajasthan 333 031, India
E-mail: vk_aggarwal@rediffmail.com, vohra64@gmail.com

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Coating of lossy material is done on the helix support rods to absorb reflections in a helix travelling wave tube. Carbon is a very commonly-used material used for this type of coating, but other materials may also be employed for this purpose. In the present work coatings of carbon, nickel and iron have been done and evaluated for the attenuation performance at microwave frequencies. Three alumina rods have been coated with different methods to characterize them for attenuation. One alumina rod has been coated with carbon using the pyrolytic deposition method, while two others have been coated with iron and nickel using the electro-deposition method. An experimental set-up involving a narrow-height waveguide with a hole was used to measure the attenuation of the coated rods at 6.0 GHz frequency.

**Keywords:** Attenuator materials, Travelling wave tube, Helix, Reflections

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## 1 Introduction

The travelling wave tube[1-3] (TWT), as shown in Fig. 1, is a microwave amplifier used for high gain and broadband applications in a communication system. The major components of a TWT are electron gun, slow-wave structure, PPM focusing system, I/O couplers and collector for collecting the spent beam. It works on the principle of distributed interaction between the electric field and the electron beam. A special type of RF circuit known as the slow-wave structure (SWS) is employed for this purpose. Helix, made from the metallic tape or wire is a commonly used SWS for extremely wideband applications. It has been observed in the analysis of travelling wave amplification that an amount of power is reflected back from the output due to mismatch through SWS. If there is a mismatch at the input also, a portion of the signal will be reflected back towards the output. This may provide oscillation caused by feedback signal[3] when the following condition is satisfied:

$$(G - L - \rho_L - \rho_I) >> 0 \qquad \dots (1)$$

where,

$G$ = Small-signal gain of the device
$L$ = Circuit loss
$\rho_L$ = Return loss at the output end
$\rho_I$ = Return loss at input end

Coating of a lossy material is done at the helix support rods to suppress these reflections. Helix is normally supported by three dielectric rods of a material having high thermal conductivity. The coating on helix support rods forms an attenuator and is widely used in low power tubes where gain is the important factor. Such coating has significant effects on the characteristics of the device. Helix with support rods having attenuator coating is shown in Fig. 2. As the attenuator plays an important role in ensuring the stability[4,5] of a TWT, a good attenuator has the following characteristics:

(i) It should provide sufficient attenuation throughout the reqired frequency range.

(ii) The film should not contribute to any reflections.

(iii) Material chosen for deposition should be pure and of vacuum grade.

(iv) The deposited film should make a strong bond with the substrate and should be able to sustain temperature cyclings.

(v) The value of RF loss should not change with time.

(vi) The RF loss should not be frequency sensitive within the specified bandwidth of TWT.

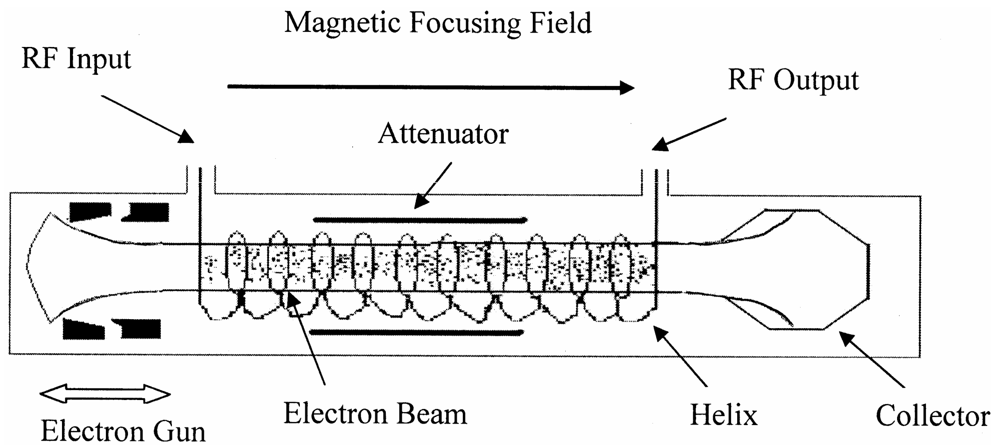


Fig. 1—Schematic of TWT

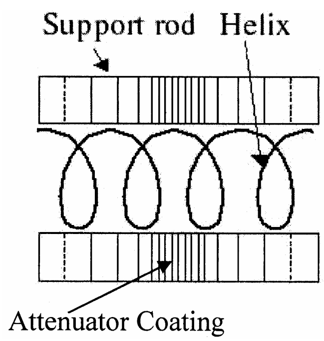


Fig .2—Coating on support rods

Although carbon is the most widely accepted choice, but a number of other materials like tantalum, nickel, iron, etc. can also be used for the attenuator coating. However, in TWTs with severs where the helix is broken and grounded with the barrel, the loss is provided at the end of the rods with gradually increasing loss up to the sever ends. Measurements on complete loss profiles have been reported elsewhere[6].

## 2 Attenuator coatings

The dielectric rods have been coated with different materials using different techniques. First cylindrical rod of alumina (1.4 mm diameter and 60 mm length) has been coated with carbon using the pyrolytic deposition method[7] . This is the most widely used technique for making attenuators for high power TWTs using hydrocarbons, like methane, heptane, benzene, etc. In coating the rod, heptane was introduced in an evacuated chamber containing support rods surrounded by molybdenum heating coil. At elevated temperatures (around 850°C), hydrocarbon cracks as a result of thermal decomposition of the organic material and carbon deposits over the support rods. Cracking of the hydrocarbon has been carried out inside a glass vacuum chamber, maintaining vacuum of the order of $10^{-2} – 10^{-3}$ torr. In another study, two alumina rods (cylindrical with 1.4 mm diameter and 60 mm length) were deposited with iron and nickel using the electrolytic deposition method. For this deposition, the rods were first coated with a 1000Å film of pure gold by evaporation method to make it conducting and these rods were then used as cathodes in the electrolysis cell. Another rod of the pure material to be deposited is used as an anode. Both the cathode and anode are then dipped in a pot containing the concentrated solution of nickel sulphate (with small amount of boric acid to improve conductance) for deposition of nickel and ferrous sulphate (with small amount of boric acid) for deposition of iron. The cell is then connected to battery and current is passed for 30 min to deposit the material. Coating of gold will not have much effect on the loss performance, since the thickness of deposited coating is appreciably less than the skin depth of material at the measurement frequency.

## 3 RF measurement set-up

Return loss and insertion loss measurements[8] have been done on all the three rods at 6 GHz frequency. The complete measurement set-up has been shown in Fig. 3. It consists of a sweeper signal source (model 837528) of Agilent Corporation capable of providing signal up to 20 GHz. The input signal is fed through a coaxial cable to a narrow height rectangular waveguide (34.78 mm × 4.96 mm) using a coaxial to waveguide adaptor and normal to narrow wall transition. The waveguide consists of a hole of

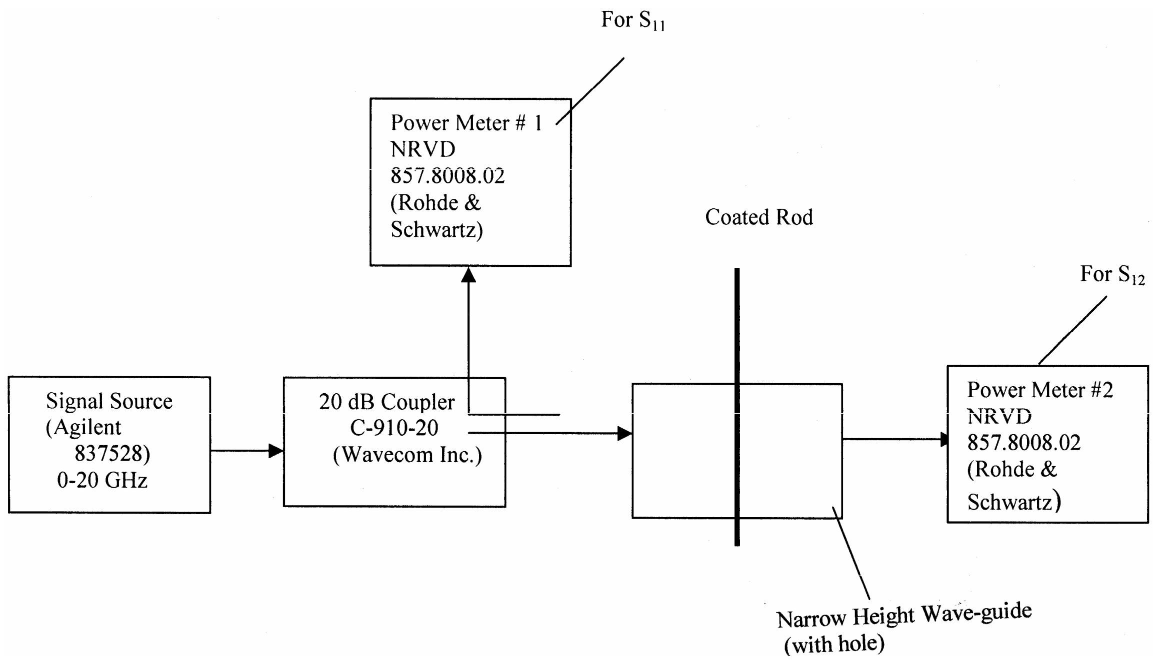


Fig. 3—RF measurement set-up

Table 1 – Return and insertion loss of attenuator having different material coatings

| Material | Return loss $S_{11}$ (dB) | Insertion loss $S_{12}$ (dB) |
|---|---|---|
| Carbon-coating | – 10.60 | – 4.8 |
| Iron-coating | – 8.73 | – 3.9 |
| Nickel-coating | – 6.00 | – 2.5 |

diameter 2 mm at the centre in which the coated rod is to be placed. Power meter #1 measures the reflected power through a 20 dB coupler and the power meter #2 has been connected to the end of waveguide using a narrow wall to normal transition and waveguide to coaxial adaptor. Measurements were done by inserting the rod in the waveguide hole and taking the power levels in both the power meters.

## 4 Results and discussion

The actual results in the form of insertion loss and return loss are given in Table 1. From these results it is evident that the insertion loss is around –4.8 dB for carbon-coated rods, –3.9 dB for iron-coated rods and –2.5 dB for nickel-coated rods with respect to the uncoated rods. Thus, carbon shows maximum attenuation and this is in agreement with the wide use of carbon for the attenuator coating. The results of the nickel and the iron coatings are also significant and these can also be used for the purpose of attenuator. Since a good attenuator must have a number of properties as already discussed in Sec. 1, the other properties of these materials may also be explored from the material science's point of view.

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## References

1 Gilmour A S (Jr), *Principles of Travelling Wave Tube* (Artech House, Boston, London), 1994.
2 Basu B N, *Electomagnetic Theory and Applications in Beam Wave Electronic* (World Scientific), 1996.
3 Gittins J F, *Power Traveling Wave Tubes* (Elsevier, New York), 1965
4 Goebel Dan M, Keller John G, Menninger Willam L & Blunk Steven T, Gain Stability of Travelling Wave Tubes, *IEEE Trans Electron Devices* (*USA*), 46 (1999) 2235.
5 Antonsen T M, Safier P, Chernin David P & Levush B, Stability of travelling wave amplifiers with reflection, *IEEE Trans Plasma Sci* (*USA*), 30 (2002)1089.
6 Kumar V, Vohra A & Srivastava V, RF Loss Profile Measurement for a high gain, broadband helix TWT, *Indian J Radio & Space Phys*, 35 (2006) 129.
7 Paik S F, Krahn H J & Smith B H, Wave propagation in pyrolytic-graphite slow-wave circuits, *IEEE Trans Electron Devices (USA)*,11(1964) 215
8 Kumar V, Vohra A & Srivastava V, Microwave Attenuation Measurements on Tetrahedral Amorphous Carbon Coatings for TWT Applications, International Conference on Materials for Advanced Technologies, ICMAT, held at Singapore, during 3-8 July 2005, 261.